Nov. 5, 1974 P. EISLER 3,846,204

HEATING METHODS

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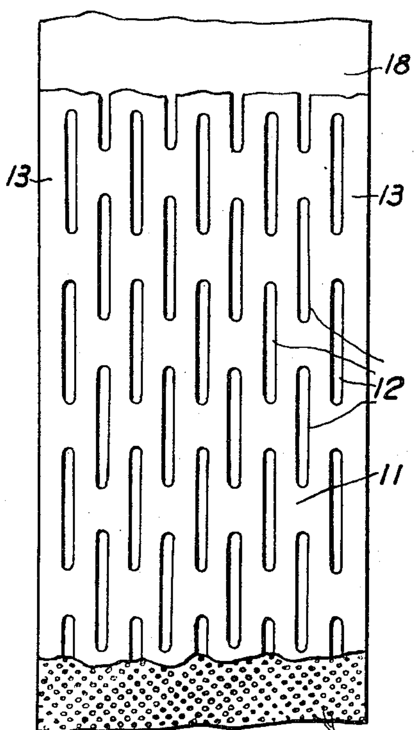

FIG. 1.

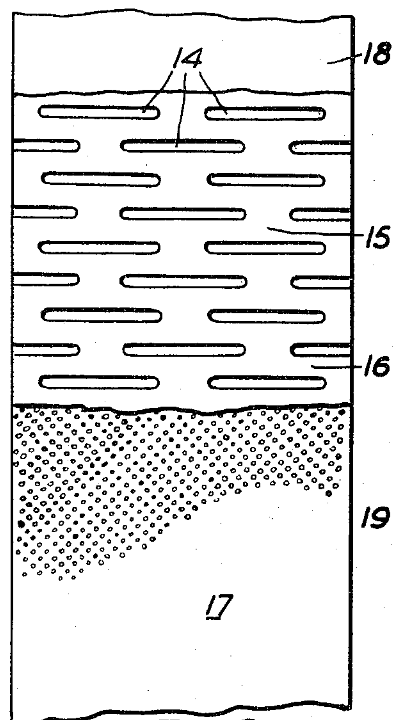

FIG. 2.

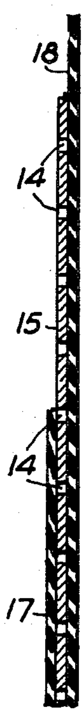

FIG. 3.

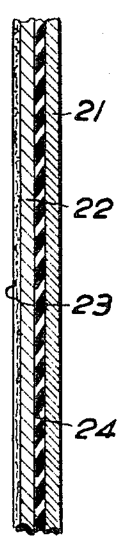

FIG. 4.

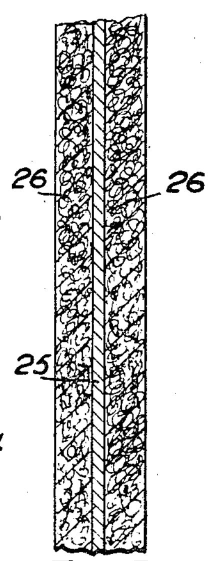

FIG. 5.

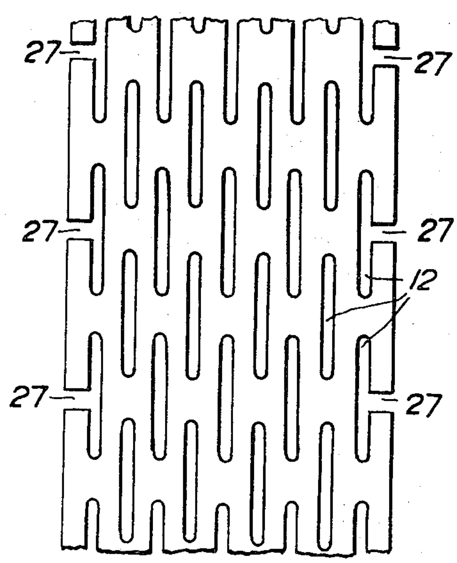

FIG. 6.

INVENTOR
Paul Eisler
BY Lawrence R Brown
ATTORNEY

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HEATING METHODS

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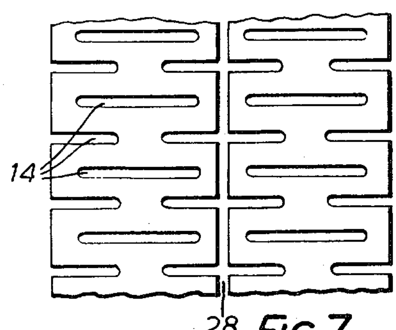

FIG. 7.

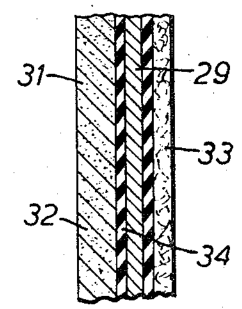

FIG. 8.

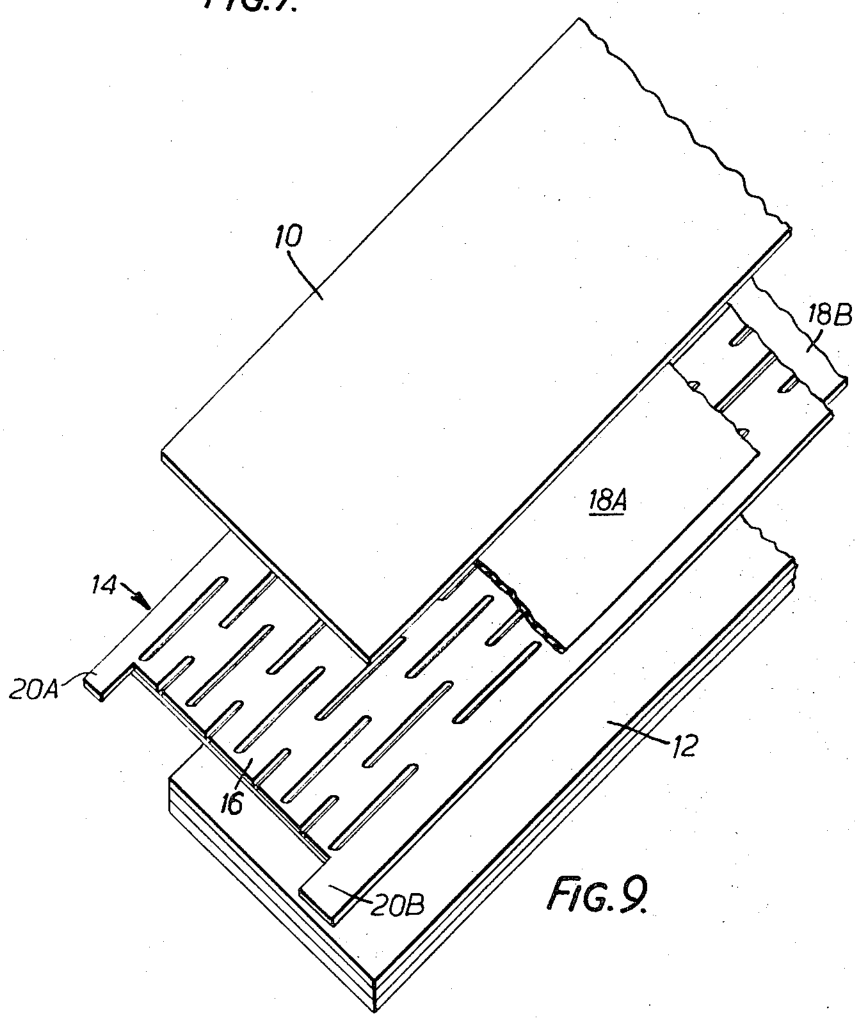

FIG. 9.

INVENTOR
BY Paul Eisler
Laurence R. Brown
ATTORNEY

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3,846,204
HEATING METHODS

Paul Eisler, 56 Exeter Road, London, N.W. 2, England

Continuation-in-part of application Ser. No. 711,416, Mar. 7, 1968, now Patent No. 3,523,542, which is a continuation-in-part of application Ser. No. 293,953, July 10, 1963, now Patent No. 3,372,487, which in turn is a continuation-in-part of application Ser. No. 783,609, Dec. 29, 1958, now Patent No. 3,099,540. This application June 1, 1970, Ser. No. 42,084
Claims priority, application Great Britain, Jan. 7, 1958, 582/58
Int. Cl. B29c *19/06;* B44d *1/48*
U.S. Cl. 156—275 4 Claims

ABSTRACT OF THE DISCLOSURE

An electrical resistance heating film operated at a voltage below 50 and developing uniform surface heating is used where heat is required in accelerating a chemical reaction or a combination of chemical and physical reactions, as in the setting of plastics materials and paints, but where temperatures may be critical and the avoidance of hot spots essential. The film may be perforated to permit passage of fluid.

This invention is a continuation-in-part of my application Ser. No. 711,416, filed Mar. 7, 1968, now Pat. No. 3,523,542 for Drying Method and Means, itself a continuation-in-part of my application Ser. No. 293,953, filed July 10, 1963, for Drying Method and Means (now matured into Pat. No. 3,372,487) which was in its turn a continuation-in-part of my application Ser. No. 783,609 filed Dec. 29, 1958 for Electric Foil Resistance Drier (now matured into Pat No. 3,099,540).

The invention relates to electric heating under conditions in which particular advantage can be taken of the characteristics of electric resistance heating films that is to say heating elements comprising an electrically conductive surface pattern distributed over it. The film could be a thin layer of insulating material such as paper covered with a conductive coating of carbon or graphite particles to which connection is made by low resistance metallic foil busbars or terminals (see for example FIG. 11 of my Pat. No. 3,033,970 and FIGS. 46 to 48 of my Pat. No. 3,296,415) but preferably it is a patterned metallic foil as described in my Pats. No. 3,033,970, No. 2,971,073, No. 3,020,378 and especially No. 3,283,284. Such films need not consist of more than the foil pattern iteself but usually the foil will be coated or covered on one or both sides with insulation, e.g. lacquer or thin paper.

Such heating films can readily be made with a pattern which represents a substantially uniform surface loading and therefore substantially uniform development of heat over the surface area. In particular cases the loading can be made different in different parts of the surface. They can be made thin and flexible and by crimping the foil made readily deformable in their own plane as well as perpendicular thereto so that they can be disposed close to intrisincally curved surfaces. Their thinness gives them very low thermal inertia so that their temperature can be rapidly and accurately controlled. They are readily made so that they can be operated under voltages below 50 and preferably considerably below 50, say 12, 6 or even lower. They are also cheap to make, using aluminium foil for the conductive pattern.

The current used will generally be in the range of amperes while the resistance of the pattern will be in the range of ohms as distinct from milli-ohms or kilo-ohms. Desirably conditions are chosen so that the voltage drop

across the pattern is of such a low value that it is not dangerous to human contact, that is usually below 50 volts.

Because of these characteristics they are specially useful in cases in which heat can speed up such an operation as drying or chemical reaction or both, without the risk of the disturbances which can occur if a certain critical temperature depending on the particular case is exceeded. The uniform heat distribution obtained with such films avoids hot spots and thus enables the film as a whole to be carried up to a temperature not far short of the critical temperature thus enabling the maximum of heat to be used with the minimum of risk.

The particular field of use which the invention is concerned is the drying, setting and curing of materials involving chemical reactions, such as paints, adhesives, synthetic resins and other plastics, especially in cases in which the film remains part of the finished structure so that the structure can be reheated at any time.

In all cases in which it may be desirable the film and any layers which may be used on either side may be of mesh or otherwise perforated form to permit or facilitate the passage of fluid such as vapour through it, for instance a solvent in the material under treatment.

The invention will be further described with reference to the accompanying drawings in which:

FIG. 1 is a plan view of one form of heating film used in the invention with some parts broken away;

FIG. 2 is a plan view of an alternative form;

FIG. 3 is a section which applies equally to FIG. 1 or 2;

FIG. 4 illustrates the application of the invention to the drying of paint;

FIG. 5 illustrates the application of the invention to the curing of plastics;

FIGS. 6 and 7 illustrate developments of the conductive pattern of the films of FIGS. 1 and 2 respectively;

FIG. 8 is a detail section illustrating a further development; and

FIG. 9 is an exploded isometric view of an assembly of two sheets of material to be bonded, with a dry adhesive film in accordance with the invention, partly cut away for the sake of clarity.

In the form shown in FIG. 1 the conductive pattern is a thin flexible metallic foil **11** having a series of slots **12** which leave a plurality of parallel meandering paths extending from terminals **13** constituted by the areas along the sides of the pattern. If the width of the arms of the pattern is kept constant each meandering path from one terminal **13** to the other will present the same overall resistance and the same resistance per unit length and if a voltage is maintained between the terminal areas the same current will flow in each path whatever the length of the film. There will thus be a substantially constant dissipation of heat per unit area over the whole film. The film shown in FIG. 1 can moreover be cut into narrower pieces since any portion between adjacent lines of slots can serve as a terminal. It will be clear that however many mander paths are left between the terminals the cross sectional area of the terminals is greater than that of the arms of the meander pattern so that the development of heat in the terminals is less than elsewhere. The same result can be obtained by adding metal of higher conductivity to the terminal areas as by clamping or plating.

In FIG. 2 the pattern is similar to that in FIG. 1 but the slots **14** extend across the foil **15** and the terminal areas **16** are at the ends. Such a film can be cut into pieces by transverse cuts as any portion between successive lines of slots can serve as terminals.

In some cases the film need not consist of anything more than the metal pattern, but if necessary or desired there may be an insulating film indicated at **17** on one side of the foil **11** or **15** and there may be another indicated at **18** on the other side. Such insulating film may be of plastic or paper for example.

In general structure in connection with which the film is used will be a multi-layer structure of which one layer is a layer containing an absorbed fluid to be heated, and the structure at the time the current is switched on will be at room temperature. Where the heating operation causes vapours to be driven off and these vapours have to escape on the same side as that to which the heating film is applied the heating film will have small passages through and it will be made porous or perforated as indicated at **19**, FIGS. 1 and 2 to allow for the passage of vapour without harm to it or the structure on which the film is used. Such small passages may be useful in other cases. In many cases the heating film itself will be of cheap construction so that it can be thrown away after once using but the invention also includes cases in which the film is retained for repeated use whether in connection with the same layer or by transfer from one layer to another. Often the heating film is provided with an adhesive coating for example a self-adhesive pressure sensitive material to permit easy fixing to the structure.

It is desirable to ensure that if the film is to be used repeatedly but on different layers it can be transferred from one to another without suffering damage because if the pattern is damaged and is still conductive, the distribution of resistance will be affected and there will be a risk of hot spots. If on the other hand it is made of cheap construction so that it can be thrown away it should be desirably made so flimsy that it is practically impossible to avoid destroying it in removing it after use.

In all cases where the pattern can be contacted by a human operator it is so designed that the necessary heating effect can be obtained by a supply of electric current at a low voltage that is to say at a voltage which does not constitute a risk to the operator if he comes into accidental contact with the pattern. Such voltages are usually below 50 and often well below 50, say 12 volts, 6 volts or even lower. Such voltages also make it permissible in many cases e.g. where the layer to be dried is not conductive, to allow the layer to touch the bare pattern. These voltages have the advantage of simplifying the construction of the film and its use, since the insulating problems presented by high voltages do not arise. It also makes it possible to use the heating films for such domestic purposes as the drying of foot-wear, clothing, towels and the like or other textile fabrics.

Other fields of use are in connection with the drying and curing, or the drying, curing and heating of paint and similar materials, and of plastic structures and fabrics.

Thus one major field of application of the heating film is its incorporation in structures which are painted. The incorporation may be temporary or permanent. It is proposed for instance to stick a heating film **21** FIG. 4 on the underside of sheet metal work indicated at **22** before it is painted as at **23**. Since the workpiece is metallic there must be an insulating layer between the actual pattern and the workpiece as at **24**, but this may be part of the heating film. No insulating layer is shown on the other side of the film **21** but it can be provided if desired. The paint is now dried by supplying current to the heating film instead of by the present methods of stoving the panels or applying heat to them by other means. Since metal is a good heat conductor, the heat from the film **21** reaches the part **23** without a steep temperature gradient or in other words the part **23** brought to a temperature a little below that reached by the film **21** and due to the layout of the conductor in the film **21** the heating is substantially uniform over the whole surface. This not only gives an improvement in drying or curing conventional paints but it often permits the substitution of stoving enamels for air drying paints.

Another major field of application is the incorporation of the film in plastic structures and fabrics such as low pressure laminates, articles made with potting resins, plastic castings and larger scale mouldings requiring heat for quick setting. FIG. 5 shows by way of example an embodiment with the heating film **25** (which here can be a bare foil pattern) between two layers **26** of fibre-glass and uncured resin i.e. within the thickness of a plastic structure. The slow drying and curing process of these plastic fabrics is at present hindering the use of these in many industries requiring speedy output from the moulds, presses or jigs for their formation. Thus the production of glass-fibre structures by the so called wet-lay process is restricted for mass production applications by the practical difficulty of and equipment required for accelerating the heat drying and curing of the structure. The incorporation of the heating film in such structures enables them to be dried and cured quickly and the moulds to be liberated more frequently with consequent saving in floor space and equipment. Heating films incorporated in plastics preferably have small passages (i.e. small holes or pores) through which the fluid resin can flow.

It should be mentioned that the term plastic is used herein to indicate not only materials which when cured are substantially rigid but also materials which are elastomeric, such as natural and synthetic rubber, and polyvinyl chloride.

The invention can be applied to two-step processes in which evaporation of a solvent is succeeded by curing. An example is a fabric such as cotton cloth coated or impregnated with thermosetting resin in a solvent. The resin may be an alcohol-soluble phenolic and the solvent an alcohol with, say, a boiling point at 78° C. The resin layer alone may be one which can be cured suddenly, that is within seconds by raising it to 150° C., while the fabric cannot safely be exposed to more than 150° C. In such circumstances the heating film is first operated to raise the layer to say 70° C. which results in all alcohol evaporating quickly but gently before the resin can set and immediately the film is dry of solvent raising the heating film to 120° C. at which temperature the cure is complete after some minutes.

Other resin solutions may be treated in a similar way. For instance, a surface coating to be produced on an aluminum sheet using the epoxy resin "Aroldite" 985 E (supplied by CIBA A.R.L. Ltd., Duxford, Cambridge) in a solvent mixture. The heating film (made with asbestos paper and sodium silicate as an insulating support for the conductive pattern) is fixed permanently or temporarily to the back of the aluminum sheet and first raised to below the boiling point of the solvents. If it were then raised to 340°–350° C. it would effect the curing of the resin in less than one minute but tests at this temperature of sudden transition have resulted in unevenness, dicolouration, local brittleness and adhesion failures. Raising the heating film to 240° C. however resulted in a good film in just over 10 minutes. Not all resin solutions require a two or more stage heating. A urea formaldehyde glue applied to a veneer which is laminated to a wooden base will serve as an example. The glue is an aqueous solution of a urea formaldehyde and a hardener such as ammonium chloride. It is not required to evaporate the water first; it disappears into the wood and the heating film can be operated to give a temperature of 120° C. at once. The "sudden" curing temperature of the glue is much nearer to 150° C. but this temperature would damage the wood and be too great a risk for the urea which rapidly deteriorates around this temperature.

The following are examples of substances which have a much narrower range of temperature for the physical or chemical reaction characteristic of them.

a. Gelation of P.V.C. paste

The paste consists of a paste polymer (such as Geon 121 supplied by British Geon Ltd.) which is a powder with particles of 1 to 2 micron size, ester plasticiser (such as dioctyl phthalate or tricresylphosphate) and a stabiliser (such as dibasic lead sulphate). It has a fusing temperature of 170° C. which is also the limit or near the limit of the temperature endurance of the gelled film. The heating film operated to attain 150° C. gels the paste within a few seconds in safety.

b. Sintering of Teflon emulsion

This emulsion of polytetrafluorethylene contains discrete fine particles which must be heated for a very short time only to 450° C. to sinter together. Local overheating causes breakdown of material while a temperature substantially lower fails to cause sintering.

Further examples comprise substances coming between the two previous groups. They are, for instance, solventless films of resins and hardeners or elastomeric compounds in which the method of invention does not so much bring a marked improvement in the control of the physical and chemical reactions apart from their acceleration but does afford other savings and advantages.

The case of resin impregnated glass fibre mouldings is described in this specification at a later stage and the examples given are only typical. Usually the impregnant is a solventless polyester, epoxy, silicone resin or another compound the cure of which can be accelerated by heat below the rate at which the setting and hardening is a matter of seconds for a thin film.

The present invention can also be applied to the drying of wearing apparel of any kind from hat to shoe. Such devices as inserts or covers for all sorts of clothing including tie-stretchers, shoe-trees and shoe-cases, may be provided with the heating film. At present such devices are mainly used as purely mechanical aids to fix, stretch or hold the clothing in position or bring it into a desired shape while it is air drying. For these purposes a porous or perforated heating film with ample openings is used which is connected to a source of very low voltage (battery or secondary of a transformer) to be incorporated in or attached to the above devices either permanently or as a dispensable item (to save cleaning or the expense of making them robust).

Methods in accordance with the invention can also be used to accelerate the action of thermosetting adhesive materials and to activate hot melt adhesives. Within this field of application the invention extends to a very convenient novel method of bonding any two materials together and laminating sheet materials such as wood, wood veneers, plastics sheets and films, sheet metal and metal foils, in which the advantages of the known dry adhesive films and tapes are combined with those of the subject electric heating method. The surfaces of the two materials to be bonder together must mate and be of a shape to which a heating film can be fit. They must therefore be preferably plane surfaces or have a shape which can be developed out of a plane.

In accordance with this aspect of the invention a method of bonding a surface of first material to a mating surface of a second material comprises the steps of applying to at least one side of a heating film as above described a thin layer of a preferably dry adhesive, that is to say an adhesive material which is dry at ordinary temperatures, to obtain an adhesive sheet and preferably to form a dry adhesive sheet; interposing the adhesive sheet between the said surfacs of the first and second materials into good heat conductive contact therewith; and passing an electric current through the surface pattern of the said heating film of sufficient intensity to raise the temperature to a value effective to activate the said adhesive, while applying appropriate bonding pressure to the assembled materials and film for the time required to effect bonding.

This embodiment of the invention will be further described with reference to FIG. 9 of the accompanying drawing which illustrates the application of a method in accordance with the invention to the bonding of a sheet **10** of synthetic resinous material e.g. that widely sold as a hard wearing and decorative surface finishing under the trade mark "Formica," to a sheet **12** of plywood by means of an interposed dry adhesive film **14**, the latter comprising a heating film **16** bearing on each of its two surfaces a layer **18A**, **18B** of a thermosetting synthetic resinous adhesive, typically phenol formaldehyde or urea-formaldehyde resin in the B-stage. The heating film has terminals at **20A**, **20B**.

The assembled layers are brought together under pressure, for example in an ordinary cold press, not shown, or by means of clamps, a suitable source of electric current, also not shown is connected to the terminals, and the current required to raise the temperature of the glue line to the required elevated value is passed for the time required to set the already partially cured resin. After removal from the press the protruding edges and terminals of the film **16**, **18** are trimmed off.

If the finished article is itself required to embody integral heating means, say for example that the laminate is to serve as the base of a food warming tray, the heating film will be selected and/or trimmed to match the dimensions of the article and the terminals will be retained for subsequent use.

The dry adhesive film, itself a novel article of manufacture, can be manufactured and sold for general use as a non-sticky self-heat dry glue film, for the same applications as present adhesive tapes and films, for bonding all types of surfaces, including metals with appropriate choice of heat activatable adhesive layers, having the significant advantages over such products of requiring no hot press or other external heating arrangements and of readily permitting precise temperature control.

Of particular advantage is the convenience and speed of effecting the bond. The whole area in the glue line is heated by the electric current to the desired temperature exceedingly quickly while the adherents remain practically cool, except for the heat of conduction from the adhesive in the glue line. The safety of the operation is guaranteed by the low voltage with which the heating film is energised.

Different adhesives may be used on the respective surfaces if desired having regard to the intended use.

To facilitate temperature control it is possible to embody in the adhesive layers or to apply thereto one of the commercially available temperature indicating paints which change colour at a predetermined temperature, for example the paints sold under the trade mark "Thermindex." Alternatively one may use a conventional temperature indicating crayon melting at the required temperature.

I claim:

1. The method of heat processing at a temperature within a predetermined range a critical material to change its physical state between fluid and solid form without a sudden undesirable transition of state caused by temperatures outside said range, comprising the steps of providing a layer of said material, bringing into thermal contact with said layer a heating film occupied by an electrically conductive surface pattern uniformly distributed to provide a substantially constant temperature throughout the heating film, and passing an electric current through said surface pattern of such intensity to provide a temperature within said range in said layer of said material wherein the material is a liquid material requiring solidification produced by chemical reaction, including the step wherein the layer of material is provided on a durable carrier structure wherein the material is a layer of fluid paint containing a fluid medium and a solid film forming substance covering at least parts of said durable structure, and including the steps of covering the major part of the area of said heating film with said conductive surface pattern, and providing said current at a first intensity to raise the temperature at any point on the surface pattern in a range without the maximum at any point on the surface pattern reaching the boiling temperature of the

fluid paint and subsequently at sufficient intensity to raise its temperature in a range without maximum at any point on the surface pattern reaching the temperaure of sudden hardening of the paint.

2. The method set forth in claim 1 including the step of providing sheet metal as the durable structure with the paint on one surface thereof and the heating film on the other surface thereof.

3. The method of heat processing at a temperature within a predetermined range a critical material to change its physical state between fluid and solid form without a sudden undesirable transition of state caused by temperatures outside said range, comprising the steps of providing a layer of said material, bringing into thermal contact with said layer a heating film occupied by an electrically conductive surface pattern uniformly distributed to provide a substantially constant temperature throughout the heating film, and passing an electric current through said surface pattern of such intensity to provide a temperature within said range in said layer of said material wherein the material is a layer of plastic incorporated with a solvent, the setting and hardening of the plastic being capable of acceleration by heat, including the steps of disposing the plastic as a layer on a structure at rest, and restricting said current intensity in a range to raise the temperature of the plastic without the maximum at any point on the surface pattern reaching the boiling temperature of the solvent until all the solvent has been evaporated, and thereafter increasing the intensity of the current in a range sufficient to raise the temperature of the film to a value which accelerates the setting and hardening of the plastic without the temperature at any point on the surface pattern reaching that of the sudden setting and hardening of the plastic.

4. The method of heat processing at a temperature within a predetermined range a critical material to change its physical state between fluid and solid form without a sudden undesirable transition of state caused by temperatures outside said range, comprising the steps of providing a layer of said material, bringing into thermal contact with said layer a heating film occupied by an electrically conductive surface pattern uniformly distributed to provide a substantially constant temperature throughout the heating film, and passing an electric current through said surface pattern of such intensity to provide a temperature within said range in said layer of said material wherein said material is an adhesive material which can be activated by heating including the steps of applying said material to at least one side of the heating film, interposing the adhesive sheet thus formed between the surfaces of two materials with good heat conductivity contact therewith, selecting said current intensity in a range activating said adhesive and applying appropriate bonding pressure to the two materials and said adhesive sheet.

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DOUGLAS J. DRUMMOND, Primary Examiner

U.S. Cl. X.R.

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